

Inhibiting Adaptation¹

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Abstract

It is widely believed that whether we are talking about command and control teams, joint task forces or coalition forces, the “organization” must be adaptive. Unanticipated changes in mission, rapidly evolving technologies, intelligent and changing opponents, and so forth have created a need to create forces that can respond rapidly, accurately and can readily adapt to new situations. Over the past decade, progress has been made in understanding the set of factors that enable adaptation. If the opposing force can be made less adaptive, more predictable, more consistent then it will be easier to contain or constrain their activity. Consequently, it may be important to mitigate the adaptivity of the opposing force in order to minimize the need for both adaptability and high performance. Thus, we turn the question on its head and ask, “How can we inhibit adaptation?” This paper reviews the findings on what makes organization’s adaptive and provides suggestions for how to inhibit adaptation. A number of lessons learned about how to inhibit adaptiveness are presented.

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1 Introduction

It is widely believed that whether we are talking about command and control teams, joint task forces or coalition forces, the “organization” must be adaptive. Unanticipated changes in mission, rapidly evolving technologies, intelligent and changing opponents, and so forth have created a need to create forces that can respond rapidly, accurately and can readily adapt to new situations. Over the past decade, progress has been made in understanding the set of factors that enable adaptation. It was previously discovered that it might not always be possible, particularly in the short run, to be both adaptive and extremely high in performance [Carley & Ren, 2001]. If the opposing force can be made less adaptive, more predictable, more consistent then it will be easier to contain or constrain their activity. Consequently, it may be important to mitigate the adaptivity of the opposing force in order to minimize the need for both adaptability and high performance. Thus, we turn the question on its head and ask, “How can we inhibit adaptation?” This paper reviews the findings on what makes organization’s adaptive and provides suggestions for how to inhibit adaptation. A number of lessons learned about how to inhibit adaptiveness are presented.

In this paper, to increase generality, the term “organization” will be used to refer to the group – whether it is a JTF, C³I architecture, a coalition force, a cellular or network organization, and so on. Not all findings will be applicable to all organizations; but, in general, most will be applicable to the organization of interest to the reader. A key feature of organizations is that their architecture can be represented as a multi-network composed of people, resources, knowledge, tasks and the relations among them [Carley & Krackhardt, 1999; Carley, Ren & Krackhardt, 2000]. Another key feature is that organizations adapt by altering the set of people, resources, knowledge or tasks, or the relations among these entities.

2 Multi-Agent Network Models

It is widely recognized that organizations are complex adaptive systems. As such, they are frequently and appropriately studied using computational models; particularly, multi-agent models. Using such models it is possible to examine the root causes of adaptability and its linkage to individual learning. In multi-agent models social behavior grows out of the ongoing interactions among and activities of the intelligent adaptive agents within and outside of the organization. For the work in organizations, researchers use not only multi-agent models but connect these agents through the multi-network. The resultant multi-agent network models are particularly suited for examining the factors making these organizations adaptive or maladaptive.

Most computational organizational models represent the organization’s architecture as a meta-network linking two or more of the following entities — agents (personnel and information technology), resources, knowledge and tasks. Thus, the actions of each agent are constrained and enabled not just by the activities of other agents but by what resources or knowledge they have, what tasks they are doing, the order in which tasks need to be done, the structure of communication and authority, and so on. Within these models, the agents are intelligent, adaptive and computational information processing systems. As noted by Carley (1999) “[a]ny entity composed of intelligent, adaptive, and computational agents is also an intelligent, adaptive, and computational agent.” Thus organizations, like humans, are intelligent adaptive agents whose behavior emerges out of the actions of the member agents and the complex interactions in the meta-network [Carley, forthcoming].

In keeping with the research in cognitive science, the agents representing humans are both cognitively and socially constrained [Simon, 1955; 1956; Carley and Newell, 1994; Carley and

Prietula, 1994]. Thus, their decision-making ability, actions, and performance depend on their knowledge, structural position, procedures and abilities to manage and traverse these networks. The same is true of artificial agents. The ability to manage or control these organizations is, at least in part, a network management task. This task involves being able to search for relevant people and knowledge, dynamically generate and evaluate the capability of individuals and groups that are networked together to achieve some goal, and to assess the vulnerability of the organization to various types of stressors (such as loss of personnel, resources or knowledge). A change in any one of the underlying networks can potentially result in a cascade of changes in the others. For example, an individual's discovery results in change in the knowledge network and in turn leads to change in the interaction network [Carley, 1991]. Understanding this meta-network and the way it evolves and can be altered is key to effective organizational command and control, it is key to enabling and inhibiting adaptation, and it is key to management.

Although the results on adaptation will be drawn broadly, in general they will be illustrated using two specific multi-agent network models. The first model is ORGAHEAD [Carley & Svoboda, 1996]. Results from this model and from other work in the literature have led to a number of findings vis adaptation. The second model, that is used to focus on issues of destabilization, is CONSTRUCT-O [Carley, 2001; Carley, 1999]. Results from this model have been used to look at issues of network evolution. Since these models, and others of this ilk, involve intelligent agents it is critical to define the difference between organizational adaptation and learning. Learning occurs when the individual or group gains new knowledge. This can be the creation of knowledge nodes or the addition of agent to knowledge links in the meta-network. Adaptation occurs when the performance of the organization is maintained or improved in the face of change. In these models, the basic adaptation cycles centers on learning. Individuals are engaged in a cycle of interacting, communicating, learning, and changing whom they interact with which is intermittently interrupted when the need to make a decision arises.

3 Previous Lessons Learned About Adaptation

Learning is ubiquitous and a fundamental feature of humans. Since adaptation results in part from learning it is impossible to totally prevent adaptation. The best that can be achieved is to limit the adaptability or control the direction of adaptation. Organizational architectures vary in the extent to which they enable or inhibit adaptation. Moreover, there are different types of adaptation. One type of adaptation is re-active - rapid change to a rapidly changing environment. Another type is pro-active – design to minimize the chance of error cascades. Teams are often adaptive in the short run due to a re-active strategy. Hierarchies can exhibit long-term adaptivity if they employ a pro-active strategy.

Previous work has suggested that the factors that enable adaptivity are often counter, at least in the short run, to high performance [Carley & Ren 2001]. Summarizing this work we found that organizations were more adaptive when there was a greater need for individuals to negotiate with each other to get tasks done, individuals had higher cognitive load (more to do), and there was redundancy in access to resources and assignment to tasks. Moreover, organizations where there was a common operation picture were more adaptive. Common operational picture was specified as individuals knew who was doing what, who knew what; i.e., individuals had an accurate transactive memory.

In terms of inhibiting adaptation these results suggest that to mitigate adaptation excess capacity (money, resources, personnel) should be eliminated, redundancy reduced (e.g., by increasing the number of tasks, the number of types of resources, and increasing the cost of redundancy), additional tasks should be taken on. Additionally, placing legal and economic

barriers on changing the C3I architecture can inhibit adaptivity. If organization shaking is encouraged – large scale turnover or change in high level personnel or goals, this will in effect, at least in the short run, reduce redundancy or at least make the existing redundancy ineffective. From a knowledge perspective, a decrease in redundancy can be achieved by, e.g., creating lots of simple tasks, discouraging job swapping, limiting training, and providing information on a need to know basis.

Reducing cognitive load can mitigate adaptivity. This can be achieved, e.g., by giving personnel less to do, giving them simpler tasks, ordering the tasks such that there are fewer dependencies among task so that the individual relies on fewer other and is less relied on, discouraging interaction so that individuals talk to fewer others, and so on. Adaptivity can be reduced by inhibiting the development of a common operational picture or by making the current picture rapidly move out of date. This can be done by taking steps to prevent individuals from building a transactive memory or destroying the accuracy of that memory. Ways of limiting transactive memory include altering phone books and web pages, move personnel without providing forwarding information, make tasks simpler and requiring less information so that there is less need for negotiation, destroying referential databases (databases that provide information on who knows what and is doing what, lower and inhibit joint training. Since adaptive organizations tune, i.e., change who is reporting to whom and who is doing what, things that inhibit tuning should make the organization less adaptive as they destroy transactive memory. Similarly maladaptive organizations tend to spend excessive time bringing on and letting personnel go. This too destroys transactive memory as it makes personnel have to spend excessive time learning who is still in the organization or learning what personnel know. Thus factors encouraging such personnel changes will also inhibit adaptivity.

The case of personnel change and adaptivity is quite complicated. The removal of individuals from an organization can lead to improved, degraded or no impact on performance. Size alone does not impact adaptability. On the one hand, reducing the number of personnel reduces redundancy and so can lower adaptability. On the other hand, as personnel change it impacts cognitive load. Cognitive load includes takes in to account all the cognitive activity that an individual needs to do. Hence it is a function of the number of others that the individual talks to, depends on, is depended on by, negotiates to get or give resources, works with, the number of tasks that the individual does the complexity of those tasks, the amount of resources that the individual accesses and so on. When personnel leave, this can decrease cognitive load by reducing the number of others interacted with; or, it can increase cognitive load by resulting in the individual having to do more tasks and use more resources. This is essentially a complex non-linear process such that simple predictions about the impact of personnel change are difficult.

4 The Overarching Structure

To try and make better sense of these changes, it is useful to have an overarching framework. It was previously noted that organizations can be usefully represented in terms of the meta-network – the set of personnel, resources, knowledge, tasks and the relations among those entities. This meta-network is comprised of a variety of sub-networks including, but not limited to, the social network (interactions among personnel), the knowledge network (who knows what), and the precedence network (what tasks come before what).

At the most basic level, adding and dropping nodes or adding and dropping relations can change the behavior of networks. One way of reframing the adaptivity question is: “What is the relative impact of adding or dropping personnel, knowledge, resources, tasks or the relations

among these?" When any node or relation is removed or added to a network it can lead to an avalanche of changes – a cascade. Clearly, on average, the addition or deletion of nodes – whether they are personnel, knowledge, resources or tasks, should lead to more of a cascade than the addition or deletion of relations. The reason is simple, the addition or deletion of a node necessitates many relation changes. Whereas, the addition or deletion of a relation need not alter what nodes are present. Thus, from a relative impact perspective, changing nodes should have a greater impact than changing relations.

The question remains, across the types of nodes, will the addition or deletion of personnel, knowledge, resources, tasks lead to greater error cascades. For specific organizations, the answer depends on the specific architecture – the exact network. However, on average, some guidelines can be constructed. Note, previous work has demonstrated that maladaptive organizations change personnel and adaptive organizations tune – alter who is doing what, knows what, has what resources. In general, since removing it takes a long time to train personnel and since resources accrue status changes in knowledge or resources are more difficult than changes in tasks. These two arguments taken together suggest that there will be a ranking such that as we move from personnel to knowledge to resources to tasks the potential size of cascades decrease. Future research should examine the relative impact of adding and dropping the types of nodes. Since change in nodes, and personnel in particular, is likely to have the biggest impact on the adaptivity of the organization the rest of this paper focuses on changes in nodes.

Both adding and dropping personnel can affect the adaptivity of organizational structures. When personnel are added the number of ties or relations can increase; whereas, when personnel are isolated or leave the number of ties can decrease. Conceptually, there is a curvilinear relationship between the number of ties in the organization's structure and performance. With too many or too few ties performance can degrade. Exactly where the peak is depends on a variety of factors including the task, the information technology, and the cognitive limitations of the personnel (see Figure 1). Without knowing where this peak is for the organization in question, it is difficult to know whether adding or dropping personnel will necessarily degrade performance and make the organization less adaptive. There are also secondary factors. That is, as personnel are added or dropped, the impact of such changes on altering the adaptivity of the organization may also be a function of the number of changes made at once, the characteristics of the personnel being added or dropped, and so on.

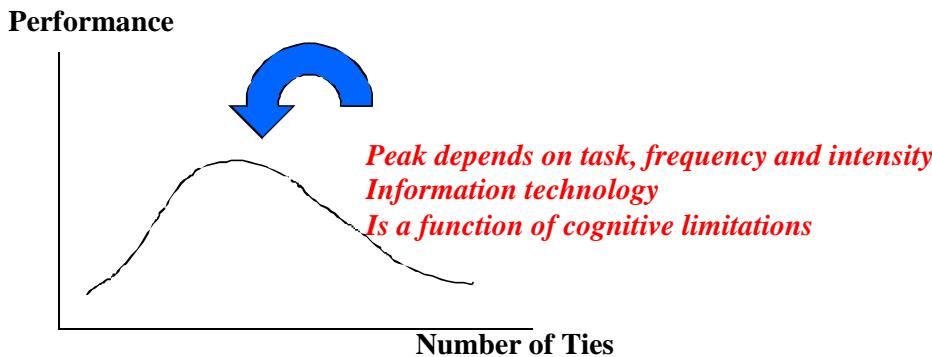


Figure 1. Conceptual Relation of Performance to the Number of Ties/Relations in the Organization's Architecture

To address this problem of adaptivity in a more systematic fashion, simulation is used. In particular, the model CONSTRUCT-O is used to examine how changes in personnel affect the

performance and rate of information in the organization. Several features of CONSTRUCT-O are salient to the ensuing discussion. First, a variety of organizational architectures can be studied in this computational framework. Second, the networks are inherently dynamic. That is, even if personnel were not added or isolated the underlying networks would change as personnel learned thus changing the knowledge network and in turn the social network. Third, this model has been used to successfully predict change in interaction in organizations and change in beliefs. Using this model, a number of virtual experiments are run to see the impact of personnel change on different types of organizations.

5 Destabilizing Structures

In general, adding personnel can inhibit adaptivity as it diverts training resources, enables you to gain intelligence on the opponent, and can lead to erroneous decisions. From a practical standpoint, adding personnel, particular to an opponent, in the hopes of destabilizing it, is a perilous and slow strategy. Basically, it takes time to build ties and so infiltrating is slow. Secondly, there is no guarantee *a priori* that you can get the right person in to the right location. A huge amount of data is needed on the opponent to determine what the right location is, and the right spot changes over time. Moreover, since individual's beliefs are a function of the beliefs of those they interact with, putting someone in to the opponent organization runs the risk that the plant will change his or her beliefs to match those with whom they are interacting.

Two points are key. First, these arguments are consistent with the way in which CONSTRUCT-O works and/or results from that model. Second, due to the impracticality of adding personnel, the ensuing analysis, and the associated virtual experiment, focus on the removal or isolation of personnel. The central question thus becomes "Who should be isolated?". A related question is, "How does the structure of the organization influence whether or not a destabilization strategy works?".

Most of the work in the field of social network analysis has focused on the removal of individuals who are highly central. One measure of centrality is degree centrality – the number of others that the individual in question interacts with. Such individuals are seen as having greater power in the organization to affect the flow of information and decisions as they are more connected. From the meta-network perspective, another candidate for isolation is the individual with high cognitive load. Previous work suggests that such individuals are emergent leaders and critical to the way in which things get done by the organization [Carley & Ren, 2001].

Using this model, previous work demonstrated that hierarchies can be temporarily destabilized by isolating the leader [Carley, Lee and Krackhardt, 2001]. However, hierarchies rapidly reform in to a new hierarchy. This is true whether the person isolated is the leader or the most central individual. In contrast, networked organizations are harder to destabilize. Moreover, the removal of the leader typically leads to many other leaders emerging. Removing the most central person may or may not lead to the emergence of multiple leaders.

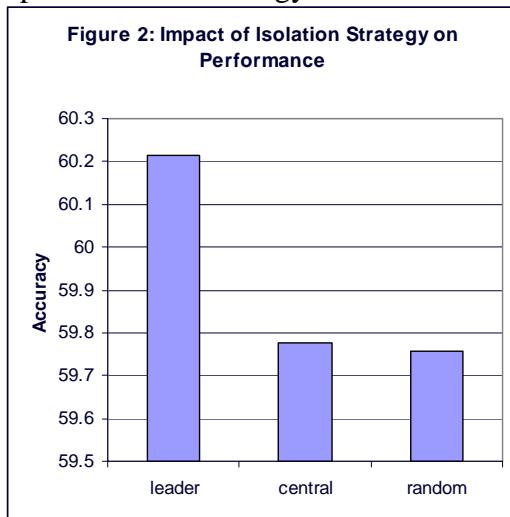
To move beyond this analysis it is critical to look at alternative networked organizations. That is, while all hierarchies behave more or less the same, the behavior of networked organizations is much more dependent on the structure. Now the relative impact of different kinds of networks are examined. There are two key ways in which networked organizations differ. First, they may vary in the extent to which they are divided in to cells. That is, on one extreme, the set of ties may be distributed evenly across the personnel. On the other hand, the personnel may be organized in to cells such that the propensity of the individuals to interact is higher within cells than between cells. Within these organizations personnel may vary in

whether they are encouraged to seek information from the “expert,” from those who are “similar” to themselves, or some combination. These organizations also vary, in terms of the available technology, for example, they may or may not have databases established to retain expertise and that can be used to facilitate training. These choices suggest the virtual experiment shown in Table 1. In all cases personnel are isolated in a continuous fashion over time.

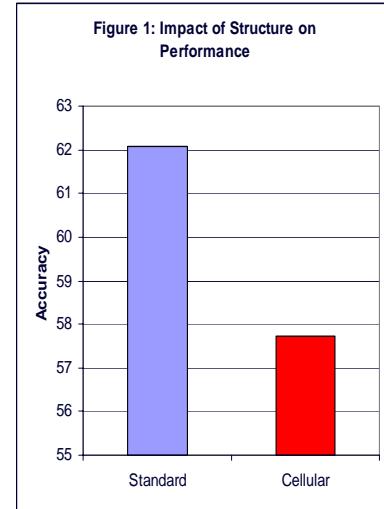
Table 1. Virtual Experiment	
Variable	Categories
Who is isolated	Central, Leader, Random
Organizational structure	Cellular, Standard
Information search strategy	Similarity, Expertise, Mixed
Database	Not Present, Present
Number of cells = 36	

The results indicate that, in general, when personnel are being continuously isolated, it will be easier to disrupt the performance of cellular organizations. While both structures can achieve high performance in the presence of attrition, the cellular’s drops further (see Figure 1). Second, we find that there is a main effect due to attrition strategy; but it is not robust.

On average, random attrition may have a slight advantage in destabilizing the underlying organization (see Figure 2). However, this effect can be reversed depending on the exact structure of the network, the information search strategy, the presence of databases, the style of communication, and so on. This suggests, however, that if intelligence is not available on these details, a random isolation strategy is likely to be effective; not the best, but satisfactory. The impact of search strategy is varied and small.



there is expertise they need. Under this condition, the adaptiveness of cellular networks can be better inhibited by using a more “socially intelligent” isolation strategy. That is, the isolation of individuals with special positions in the underlying metanetwork is more effective than random isolation on a cellular network where an information search strategy based on expertise is used. Were the personnel within the network most likely to only communicate with each other if they



A key difference between standard network and cellular network structures is that a sustained attrition strategy manages to destabilize the standard network in such a way that performance is continuously compromised (see Figure 3). In contrast, within a cellular network, efforts to destabilize it meet with mixed success. In fact, such strategies can actually lead to improvement in the cellular networked organization’s performance depending on the nature of the task being done (see Figure 4). Cellular networks are in this sense extremely adaptive. One reason for this is that the cellularization encourages rapid information flow. In figures 3 and 4 the information search strategy employed by the personnel within the networks is that of preferring to interact only when

had a lot in common then, although the cellular network would be the most adaptive, the most effective way to inhibit adaptation would be to use a random isolation strategy. In general humans use a mixed information search strategy. In that case, once again, a socially intelligent isolation strategy is best for inhibiting adaptation.

As the world becomes more informed it is expected that technology will enable greater adaptivity. In general, the idea is that information technology, such as databases, can prevent information loss and facilitate the rapid training of recruits. Preliminary results suggest that this may not be the case. In Figure 5, for example, we see that the value of databases for standard networks will be strongest in the long run when after there has been sufficient attrition; whereas, in cellular networks, in the long run databases may actually serve to exacerbate the destabilization caused

by attrition. One reason for this is that in the cellular network the strong divisionalization that enabled adaptivity is broken by the database. The results shown in figure 5 are for the case where the personnel use a mixed information search strategy, attrition is random but sustained, and the database is initially incomplete. Clearly much additional work needs to be done here, however, the results demonstrate that there may be unanticipated effects in terms of adaptivity as information technology comes on line.

6 Conclusion

This work provides guidance for how to inhibit or enhance the adaptability of an organization. It is critical to note that although the term organization is used for simplicity of exposition, the actual structures studied can be equally thought of governmental and non-governmental units, task forces, corporations, or covert networks. In general, this research provides a set of specific guidelines for how to make organizations more or less adaptive, a rank ordering across types of high-level strategies, and a detailed analysis of several personnel

Figure 3: Impact of Isolation Strategy on Performance for Standard Network

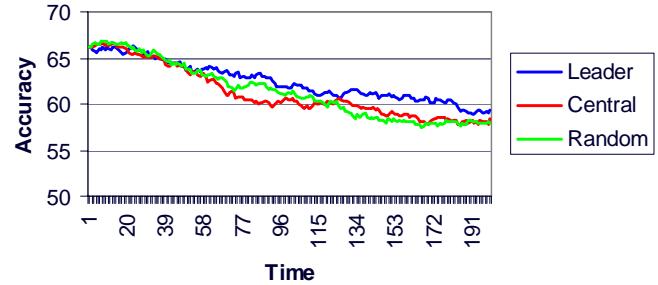


Figure 4: Impact of Isolation Strategy on Performance for Cellular Network

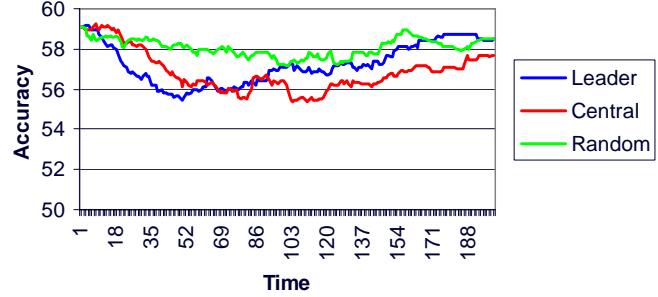
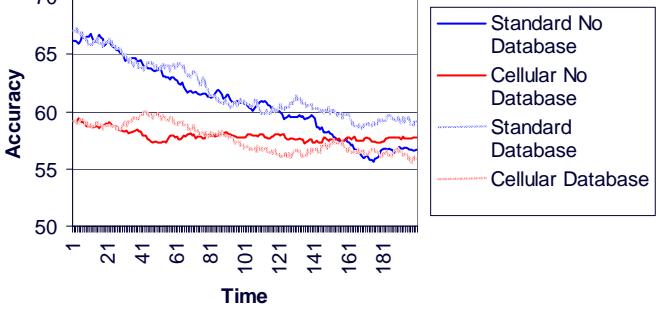


Figure 5: Ability of Database to Overcome Destabilization



isolation strategies. There are two key themes underlying these results. First, it is easier to determine how to impact the performance or the flow of information through an organization than to determine exactly how it will adapt. It is easier to destabilize a network than to determine what new goals it will form or new tasks it will take on. This is a function of our lack of knowledge about the processes of adaptation other than learning. Second, the relative impact of destabilization strategies strongly depends on the underlying organizational architecture; i.e., on the meta-network itself. As such, a key interpretation of these results is in terms of destabilizing different classes of networks.

Another factor to consider is the relatively “culture free” nature of this approach. The ability of individuals to learn and respond is a function of their cognitive capabilities and social position. Cultural differences enter in by affecting: a) the structure of the networks, b) the type of directives sent through the network (simple or detailed), and the preference for choosing interaction partners based on similarity or expertise. This makes culture a set of measurable parameters such that cross-cultural differences can be seen by setting differences in these parameters.

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